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# UNCLASSIFIED OPERATION CROSSROADS

XRD-1

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REPORT OF

## BUREAU OF SHIPS INSTRUMENTATION GROUP

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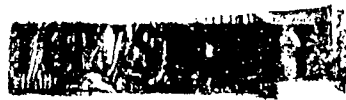
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### Strain and Displacement Measurements

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⑥ OPERATION CROSSROADS ,

Report of

Bureau of Ships Instrumentation Group

Section V

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STRAIN AND DISPLACEMENT MEASUREMENTS ,

⑩ J. G. McGinley.      ⑪ 1957,      ⑫ IV,

⑭ XRD-196

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Report of  
STRAIN AND DISPLACEMENT MEASUREMENTS

~~The installations were carried out by J. G. McGINLEY and G. A. WAGLEY. The report was prepared by J. G. McGINLEY.~~

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## TABLE OF CONTENTS

	Page
Abstract	1
Instrumentation Installations	2
Description of Gages	3
Results, Test Able	8
Results, Test Baker	19
Distance Relationships, Test Able	30
Distance Relationships, Test Baker	32
Figures 1a, 1b, 1c, 2, 3, and 4	Following 33

## RESTRICTED DATA

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## ABSTRACT

Strains and structural displacements produced by the atomic bomb explosions of Test Able and Test Baker were measured on the attack transports BRISCOE, BRACKEN, and NIAGARA and on the submarines SKIPJACK, SEARAVEN, TUNA, SKATE, APOGON, DENTUDA and PARCHE.

Without exception the measured strains and displacements produced by the explosion of Test Able were far smaller than was expected. At the most significant gage locations on the transports, the measured strains corresponded to stresses of the order of 3000 pounds per square inch. The maximum observed deflection of the ships' sides was 0.45 inch which is too small to be of structural significance.

Although the SKATE, the submarine nearest the explosion in Test Able, was severely damaged topside, her pressure hull was unharmed. The hull deflections measured on this vessel were no greater in magnitude than would result from submergence to a depth of 400 feet.

Two of the ten instrumented vessels, the submarines SKIPJACK and APOGON, were sunk in Test Baker; the other eight were practically undamaged. Moderate strains, corresponding to stresses of about 14,000 pounds per square inch were recorded at the significant gage locations on the BRISCOE, the transport which was the nearest to the explosion of the transports instrumented.

Although larger than in Test Able, the displacements in Test Baker measured on the transports again indicated that the ships' structures responded elastically to the forces produced by the bomb. Vertical deflections were predominant, reflecting the upward motion of the ships induced by the underwater explosion.

The hull deflections measured on the five surviving submarines were in no case greater than would be produced by submergence to a depth of 250 feet.

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## STRAINS AND DISPLACEMENTS

### INSTRUMENTATION

The Strain and Displacement Group installed 42 strain gages and 12 displacement gages on the attack transports BRISCOE, BRACKEN, and NIAGARA and 28 displacement gages on the submarines SKIPJACK, SEARAVEN, TUNA, SKATE, APOGON, DENTUDA, and PARCHE. The same gage layout was used for both Test Able and Test Baker without change.

On each of the three transports there were four displacement gages and 14 strain gages which are described in the next section. Two displacement gages were mounted in each cargo hold, one vertically, the other athwartships. The vertical gages measured the relative displacement between the first platform and the inner bottom in the forward hold and between the main deck and the second platform in the after hold. Both of these gages were placed about 14 feet to port of the ships' centerline, a distance sufficient to clear the hatch opening. The athwartships gages measured the relative displacement between the port and starboard shells at the second platform level in the forward hold and at the first platform level in the after hold. The ends of these gages were welded to heavy longitudinals.

The strain gages, all of which measured strains in the fore and aft direction, were placed in two belts; one on a section through the forward hold, the other on a section through the after hold. In each of these belts gages were located on the port and starboard sides of the weather deck and main decks, on port and starboard longitudinal stringers, and on the top of the keel. The gages on the keel yielded records of strain versus time; all other gages recorded peak strains only.

In each submarine, two gages, one mounted vertically, the other athwartships, measured the displacement of the hull in each torpedo room.

## DESCRIPTION OF GAGES

### DISPLACEMENT GAGES

Typical installations of displacement gages on a submarine and on a transport are shown in Photographs 181 to 184 and 186 to 190, respectively.

In order to permit access to the torpedo tubes, the displacement gages installed in the submarines were made demountable; the ends of the gages were fastened with four 1/2-inch bolts to short built-up brackets which were welded to the hull stiffeners. The displacement gages used on the transports were not removeable; the ends were welded directly to the ship's structure. With the exception of this installation detail, the gages were essentially identical.

The body of the gage consists of two pieces of steel tubing which may be termed the plunger and the sleeve; the plunger slides into or out of the sleeve as the ship's structure is displaced. The tubing weighed approximately 11 pounds per foot. The sleeve, 20 inches long and 6 1/8 inches in outside diameter, was machined inside so that it cleared the plunger, which is 5 1/2 inches in outside diameter, by about 0.01 inch all around. The length of the plunger is 10 inches shorter than the total gage length so that it is free to travel in the sleeve 10 inches in either direction.

The displacement record is scratched longitudinally on a solid cylinder of smooth brass, by two sharp-pointed steel scribers screwed into a steel guide which is welded to the plunger. The guide contains a smooth clearance hole for the cylinder which is fastened to a small plate welded to the gage sleeve. The scriber block and the small plate are installed so that the axis of the cylinder or target is parallel to the axis of the gage proper. A circumferential reference line of zero displacement was scratched before each test by screwing the scribers into contact with the brass cylinder and then rotating the cylinder through a small arc.

The athwartships displacement gages on the transports were approximately 50 feet in length; to prevent them from sagging, supporting I-beams, welded to the gage plunger and to the deck below, were placed at the third points of the gage lengths. The supports, each composed of two I-beams inclined at an angle of 60 degrees with the deck, resembled

inverted V's about nine feet in height. To allow movement in the direction of the gage axis, while providing vertical support, the flanges of the beams were removed over a length of about five inches at each end so that the webs of the beams, bending in the direction of motion of the gage, served as flexure plates.

Displacement gages are identified in this report by the letter "N" followed by a number which refers to the location of the gage on the target ship.

#### STRAIN GAGES: TIME-RECORDING

Typical installations of the time-recording strain gages are shown in Photographs 206 and 207.

The time-recording strain gage yields a record of time versus strain over a 10-foot base length. At each end of the gage length, a fixed bracket is bolted securely to a small base plate which is welded to the ship's structure. Bridging the distance between the two brackets is a bolted assembly of two equal lengths of 2-inch, standard steel pipe supported at four points by vertical flexure plates which limit the motion in any direction other than along the axis of the pipe. One end of the pipe is welded to one of the fixed brackets; attached to the other end is a projecting yoke-like fixture in the opposite arms of which are embedded a diamond scriber or stylus and a small ball bearing. The stylus scratches the time-strain record on the top side of a chrome-plated brass disc which is securely fastened to a small platen on the top of the second fixed bracket; the ball offers support to the bottom side of the disc. Both stylus and ball are held against the disc by adjusting screws which are mounted on the bracket. By means of a gear system embodied in the bracket and powered by a small electric motor, the disc is rotated at a speed of 1 1/2 RPM. A reference line of zero strain was scribed on the target discs before each test. To provide a means of cutting off the power two or three minutes after the atomic bomb explosions, a closed microswitch was wired in series with the motor. The switch was opened by the pull in a short length of fishline which was wound up and tautened by the rotating target disc.

The range of this gage in either direction was sufficient to permit recording of strains corresponding to stresses of over 30,000 pounds per square inch. The time-recording strain gages are identified in this report by the letter U' (U-prime), followed by a number which refers to the location of the gage on the target ship.

## STRAIN GAGES: PEAK RECORDING

Typical installations of these gages are shown in Photographs 192 to 204.

This gage yields a record of peak strain over a 10-foot base length. Its construction differs from that of the time-recording strain gage only in the recording end. The fixed bracket at this end of the gage is a short piece of 3-inch I-beam welded to the ship's structure. Welded to the free end of the pipe is a short tube the inner diameter of which is slightly larger than that of the smooth brass cylinder on which the record is scratched. Screwed into the walls of the tube or guide, diametrically opposite each other are two sharp-pointed steel scribes which scratch the record on the cylinder. The cylinder is inserted into the tube and then bolted tightly to the web of the I-beam bracket. As the ship's structure is strained the cylinder moves into or out of the tube and the strain is recorded directly. A reference line of zero strain was obtained by rotating the cylinder through a small arc before each test.

The peak strain gages are identified in this report by the letter "U" followed by a number which refers to the location of the gage on the target ship.

## PURPOSE OF INSTRUMENTATION

Owing to the unprecedented nature of the tests, there was a wide range of conjecture, when the instrumentation was in the planning stage, as to the effect that the atomic bomb explosions would produce on the target array at Bikini. It seemed certain that the structural response of at least some of the instrumented vessels would be far above the elastic limit with correspondingly large strains and displacements. Further, it was expected that the loading on the target vessels would be significantly different in two respects from the normal explosive experience. First, the comparatively long duration expected of the atomic bomb shock waves made it appear plausible that the vessels would be subjected to pressure from all sides practically simultaneously so that the target would be subjected to something approaching a hydrostatic loading in a manner not possible with conventional explosions. Second, the large distances at which responses were expected lead to conditions somewhat like a plane wave which strike the entire length of the ship essentially simultaneously, so that the bodily response of the vessels

might conceivably be quite different from those associated with conventional explosives. It was agreed, therefore, that the strain gages and displacement gages should have considerable range, should be of rugged construction and should be located in such a pattern that the data obtained would indicate the nature and extent of the overall reaction of the target ships on which they were placed. The variation of strain and displacement with distance from the point of detonation would be studied by installing gages at comparable locations on seven submarines and three transports anchored at various distances from the blast.

It was expected that the water pressure applied to the hulls of the five submarines submerged during Test Baker could be estimated by comparing the displacements with those measured by the builders of the vessels during deep-submergence trials.

In the submarines, the choice of gage locations was governed to a large extent by accessibility. After inspection of the submarines at Pearl Harbor, it was obvious that installation of the gages would be much less difficult in the torpedo rooms than elsewhere on these vessels in which unused space is so limited. Even in these relatively open spaces, it was necessary, at some locations, to incline the transverse gages at an angle with the deck in order to clear cables, control boxes, piping and other gear which was attached to the frames.

On the attack transports the strain and displacement instrumentation was disposed in and about the forward and after cargo holds. The choice of these spaces in which there was no interference from bulkheads or ship's machinery made the installation of the long displacement gages relatively simple. In addition, it was thought that the proximity of the strain and displacement gages to various other instruments, clustered in the troop ammunition compartment just aft of the forward hold and in the gasoline stowage space below the after hold, would permit comparison and possible correlation of the test data.

It was originally planned to install the seven strain gages at each belt as follows: one on the keel, one on each of the heavy longitudinal stringers running along the sides near the waterline, and the remaining four in pairs on the top and bottom of the weather deck near the connection to the sheer strake. Upon inspection of the transports, however, it was decided that it was not feasible to locate these latter four gages as planned and they were located singly on the weather and main decks approximately four feet from the connections to the sides of the hull. The decks at the after gage locations were stiffened longitudinally to a small extent by inverted angles welded to the under sides but there was no longitudinal stiffening at the forward gage locations.

Although it was realized that interpretation, in terms of strain, of the data obtained from the deck gages might be impossible due to local buckling of the plating, the gages were installed here for want of better locations in the hope that they might yield information that would be of comparative value. Moreover, during the planning and installation stages of the instrumentation, it was expected that the atomic bomb explosions would produce severe wave action with a resultant appreciable overall bending of the target ships. It was agreed that if the stresses resulting from such overall bending action should prove to be predominant rather than stresses caused by local buckling of the decks due to shock and blast loads, the errors in the data obtained from the deck gages would be of smaller magnitude. This would be particularly true at the gage locations in the after belt where the deck plating would receive some support from the longitudinal angle stiffeners.

## TEST RESULTS AND DISCUSSION - TEST ABLE

### DISPLACEMENTS MEASURED ON SUBMARINES

The displacements measured on seven submarines, all of which were on the surface for Test Able, and the locations at which they were measured are listed in Tables 1 to 7. The significant features of representative frame structures of the vessels at the gage locations and the manner in which the gages were installed are illustrated in Figure 1.

TABLE 1

Displacements Measured on SS-184, SKIPJACK							
Gage	Frame	----Gage Location		Displacement in Inches	Direction	In	Out
		Inches above Platform					
		Port	Starboard				
N-1	23	39	39	Athwart.	0.010	*	
N-2	27	--	--	Vertical	*		*
N-3	175	47	12	Athwart.	0.030		*
N-4	168	--	--	Vertical	*		*

\* The displacement at this location was less than 0.01 inch.

TABLE 2

Displacements Measured on SS-196, SEARAVEN						
Gage	Frame	Gage Location		Direction	Displacement in Inches	
		Inches above Platform			In	Out
		Port	Starboard			
N-1	24	42	42	Athwart.	*	*
N-2	27 1/2	--	--	Vertical	*	*
N-3	176	21	61	Athwart.	*	*
N-4	173	--	--	Vertical	*	*

\* The displacement at this location was less than 0.01 inch.

TABLE 3

<u>Displacements Measured on SS-203-TUNA</u>						
<u>Gage</u>	<u>Frame</u>	<u>Gage Location</u>		<u>Direction</u>	<u>Displacement in Inches</u>	
		<u>Inches above Platform</u>	<u>Inches above Platform</u>		<u>In</u>	<u>Out</u>
		<u>Port</u>	<u>Starboard</u>			
N-1	21	48	18	Athwart.	0.015	0.015
N-2	30	--	--	Vertical	*	0.015
N-3	118	52	44	Athwart.	*	*
N-4	112	--	--	Vertical	*	*

\* The displacement at this location was less than 0.01 inch.

TABLE 4

<u>Displacements Measured on SS-305, SKATE</u>						
<u>Gage</u>	<u>Frame</u>	<u>Gage Location</u>		<u>Direction</u>	<u>Displacement in Inches</u>	
		<u>Inches above Platform</u>	<u>Inches above Platform</u>		<u>In</u>	<u>Out</u>
		<u>Port</u>	<u>Starboard</u>			
N-1	22	23	23	Athwart.	0.180	0.030
N-2	29	--	--	Vertical	0.045	0.075
N-3	120	40	57	Athwart.	0.070	0.035
N-4	113	--	--	Vertical	0.090	0.210

TABLE 5

<u>Displacements Measured on SS-308, APOGON</u>						
<u>Gage</u>	<u>Frame</u>	<u>Gage Location</u>		<u>Displacement in Inches</u>	<u>Direction</u>	
		<u>Inches above Platform</u>	<u>Starboard</u>			
		<u>Port</u>			<u>In</u>	<u>Out</u>
N-1	22	27	27	Athwart.	0.01	0.01
N-2	29	--	--	Vertical	0.015	0.02
N-3	119	55	40	Athwart.	0.02	0.02
N-4	113	--	--	Vertical	*	*

\* The displacement at this location was less than 0.01 inch.

TABLE 6

<u>Displacements Measured on SS-335, DENTUDA</u>						
<u>Gage</u>	<u>Frame</u>	<u>Gage Location</u>		<u>Displacement in Inches</u>	<u>Direction</u>	
		<u>Inches above Platform</u>	<u>Starboard</u>			
		<u>Port</u>			<u>In</u>	<u>Out</u>
N-1	21	34	34	Athwart.	*	*
N-2	30	--	--	Vertical	*	*
N-3	120	50	56	Athwart.	0.020	0.020
N-4	113	--	--	Vertical	*	0.025

\* The displacement at this location was less than 0.01 inch.

TABEL 7

<u>Displacements Measured on SS-384, PARCHE</u>						
<u>Gage</u>	<u>Frame</u>	<u>Gage Location</u>		<u>Displacement in Inches</u>	<u>In</u>	<u>Out</u>
		<u>Inches Above Platform</u>	<u>Direction</u>			
		<u>Port</u>	<u>Starboard</u>			
N-1	22	42	42	Athwart.	0.040	0.025
N-2	30	--	--	Vertical	0.015	0.020
N-3	120	42	42	Athwart.	0.030	0.020
N-4	113	--	--	Vertical	0.020	0.030

The magnitudes of the displacements are much less than was anticipated; the instrumented submarines were among those vessels favored by the inaccuracy of the bomb drop. The records were measured with a microscope and are tabulated to the nearest 0.005 inch, but the overall accuracy is probably no greater than plus or minus 0.01 inch. Therefore, only those displacements recorded on the SKATE, the submarine nearest the center of blast, are considered significant enough to warrant discussion.

The most surprising feature of the records obtained on the SKATE is that the maximum displacement, that recorded by the vertical gage in the after torpedo room, is outward indicating an increase of the diameter of the hull on the vertical centerline. The outward vertical displacement was greater than the inward in the forward torpedo room also, but it was less than half of the athwartships displacement which was predominantly inward in both rooms.

Displacements measured on submarines of the same class as the SKATE during deep submergence trials are listed in Table 8. These records, obtained from the builders of the vessels, provide an indication of the manner in which the SKATE would respond to uniform hydrostatic pressure.

TABLE 8

Displacements Measured on SS-304, SEAHORSE, and SS-314, SHARK, During Deep-Submergence Trials

Submarine	Frame	<u>Displacements in inches at 400-foot depth</u>		
		<u>Direction</u>	<u>Inward</u>	<u>Outward</u>
SS-304	22	Athwartships	0.167	--
SS-304	30	Vertical	0.277	
SS-314	117	Athwartships		0.08
SS-314	114	Vertical	0.25	

The frames listed in Table 8 are structurally comparable to those at which displacements were measured on the SKATE at Bikini with the exception of Frame 117 which is not structurally similar to Frame 120 on the SKATE.

From a comparison of Tables 4 and 8 it is seen that the loading on the SKATE was far from uniform in Test Able. The deflections measured on this vessel indicate a much greater compression of the sides than of the top and bottom.

The only other vessel for which measurable displacements were obtained on all gages was the PARCHE. Although these deflections are small and only slightly exceed the limiting accuracy of the gages, they do indicate an unequal pressure loading with a larger compressive force on the sides than on the top and bottom.

DISPLACEMENTS MEASURED ON ATTACK TRANSPORTS

The displacements measured on the attack transports BRISCOE, ERACKEN, and NIAGARA are listed in Tables 9, 10, and 11. The gage locations are given in the tables and in Figure 2. The general structure of these ships at sections in the forward and after holds is also shown in Figure 2.

TABLE 9

<u>Displacements Measured on APA-65, BRISCOE - TEST ABLE</u>						
<u>Gage</u>	<u>Placement</u>	<u>Gage Location</u>			<u>Displacement in Inches</u>	
	<u>of Gage</u>	<u>Frame</u>	<u>Vertical</u>	<u>Athwart.</u>	<u>Inward</u>	<u>Outward</u>
N-1	Athwart.	49 1/2	2ndPltfm level	Port stringer to stbd stringer	0.14	0.03
N-2	Vertical	50	1stPltfm to top of inner bottom	13 ft. 5in. to port of centerline	0.15	0.09
N-3	Athwart.	115	1stPltfm level	Port stringer to stbd stringer	0.45	*
N-4	Vertical	116	Main Dk. to 2nd Pltfm.	14 ft. to port of centerline	0.24	0.05

\* The record of outward displacement at this location was nullified when the gage was struck by two pontoon hatch covers dislodged by the blast.

TABLE 10

<u>Displacements Measured on APA-64, BRACKEN - TEST ABLE</u>						
<u>Gage</u>	<u>Placement</u>	<u>Gage Location</u>		<u>Displacement in Inches</u>		
	<u>of Gage</u>	<u>Frame</u>	<u>Vertical</u>	<u>Athwart.</u>	<u>Inward</u>	<u>Outward</u>
N-1	Athwart.	49 1/2	2ndPltfm level	Port stringer to stbd stringer	0.07	0.02
N-2	Vertical	50	1stPltfm to top of inner bottom	15 ft. to port of centerline	0.14	0.12
N-3	Athwart.	115	1stPltfm level	Port stringer to stbd stringer	0.27	0.04
N-4	Vertical	116	Main Dk. to 2nd Pltfm.	14 ft. 2 in. to port of centerline	0.19	0.02

TABLE 11

<u>Displacements Measured on APA-87, NIAGARA - TEST ABLE</u>						
<u>Gage</u>	<u>Placement</u>	<u>Gage Location</u>		<u>Displacement in Inches</u>		
	<u>of Gage</u>	<u>Frame</u>	<u>Vertical</u>	<u>Athwart.</u>	<u>Inward</u>	<u>Outward</u>
N -1	Athwart.	49 1/2	2ndPltfm level	Port stringer to stbd stringer	0.02	0.00
N-2	Vertical	50	1stPltfm to top of inner bottom	13 ft. 7 in. to port of centerline	0.05	0.03
N-3	Athwart.	116	1stPltfm level	Port stringer to stbd stringer	0.12	0.04
N-4	Vertical	117	Main Dk. to 2ndPltfm.	13 ft. 6 in. to port of centerline	0.07	0.01

The measured displacements were much smaller than were anticipated and indicated a structural response far below the elastic limit of the ships; the greatest observed deflection was less than 1/2 inch. The results were consistent at corresponding gage locations; on each ship the largest displacement was athwartships in the after hold; the second largest was vertical in the after hold; and the smallest was athwartships in the forward hold.

In the case of the athwartships gages, both ends of which reflect the movement of portions of the ship's structure directly exposed to the blast, the displacements should be inversely proportional to the relative stiffness of the structure in each hold. The smaller athwartships displacements in the forward holds of the ships are attributed to the stiffening effect of the heavy web and face plate of Frame 48. As can be seen in Figure 2 and in Photographs 186 to 190, this frame structure has no counterpart in the after holds.

Gage N-4, measuring the relative displacement between the main deck and the second platform in the after hold, recorded a greater displacement than Gage N-2 in the forward hold between the first platform and the inner bottom. Unlike the athwartships gages, these gages measured displacements between points which were shielded from the direct blast by intervening structure. Therefore, it is impossible to determine what proportion of the difference between the vertical deflections in the forward and after holds is due to variations in loading and what proportion may be ascribed to structural differences.

#### STRAINS MEASURED ON ATTACK TRANSPORTS

Stresses derived from apparent strains measured on the BRISCOE and the BRACKEN are listed in Tables 12 and 13. The locations at which the strain gages were installed are given in the tables and in Figure 2. No strains are tabulated for the NIAGARA which was anchored on the outskirts of the target array. On this ship, the strains were below the measuring accuracy of the gages at ten of the fourteen stations and barely exceeded the limit of accuracy at the other four stations all of which were on the unstiffened decks.

TABLE 12

Apparent Stresses Derived from Strains Measured on APA-65,  
BRISCE - TESTABLE

# Gage	Gage Location			Total Elongation in Inches per 120 Inches		Maximum Apparent Stress psi $\pm$
	Frame	Vertical	Athwart.	Compression	Tension	
U-1	42-46	Wthr.Dk.	48'' from Pt. Shell	0.047	0.039	11,500C*
U-2	42-46	Wthr.Dk.	48'' from Sb. Shell	0.028	0.047	11,500T*
U-3	42-46	Main Dk.	48'' from Pt. Shell	0.014	0.029	7,100T*
U-4	42-46	Main Dk.	48'' from Sb. Shell	0.021	0.034	8,300T*
U-5	42-46	2ndPltfm level	Port Stringer	**	**	
U-6	42-46	2ndPltfm level	Stbd Stringer	**	0.022	5,400T
U'-1	42-46	Keel, top of inner bottom	Centerline	**	**	
U-7	110-114	Wthr.Dk.	48'' from Pt. Shell	**	**	
U-8	110-114	Wthr.Dk.	48'' from Sb. Shell	0.022	0.023	5,600T*
U-9	110-114	Main Dk.	48'' from Pt. Shell	**	0.011	2,700T*
U-10	110-114	Main Dk.	48'' from Sb. Shell	**	0.014	3,400T*
U-11	110-114	1stPltfm level	Port Stringer	**	0.031	7,600T
U-12	110-114	1stPltfm level	Stbd Stringer	**	0.028	6,800T
U'-2	113 1/2- 117 1/2	Keel top of inner bottom	Centerline	**	0.013	3,200T

(See NOTES following Table 13)

TABLE 13

Apparent Stresses Derived from Strains Measured on APA-64,  
BRACKEN - TEST ABLE

# Gage	Gage Location			Total Elongation in Inches per 120 Inches		Maximum Apparent Stress psi $\pm$
	Frame	Vertical	Athwart.	Compression	Tension	
U-1	42-46	Wthr.Dk.	48'' from Pt. Shell	0.041	0.024	10,000C*
U-2	42-46	Wthr.Dk.	48'' from Sb. Shell	0.047	0.040	11,500C*
U-3	42-46	Main Dk.	48'' from Pt. Shell	0.026	0.043	10,500T*
U-4	42-46	Main Dk.	48'' from Sb. Shell	0.014	0.017	4,200T*
U-5	42-46	2ndPltfm level	Port Stringer	**	0.023	5,600T
U-6	42-46	2ndPltfm level	Stbd Stringer	**	0.018	4,400T
U'-1	42-46	Keel, top of inner bottom	Centerline	**	**	
U-7	110-114	Wthr.Dk.	48'' from Pt. Shell	0.018	**	4,400C*
U-8	110-114	Wthr.Dk.	48'' from Sb. Shell	0.014	0.018	4,400T*
U-9	110-114	Main Dk.	48'' from Pt. Shell	0.023	**	5,600C*
U-10	110-114	Main Dk.	48'' from Sb. Shell	0.017	**	4,200C*
U-11	110-114	1stPltfm level	Port Stringer	**	0.053	12,900T
U-12	110-114	1stPltfm level	Stbd Stringer	**	0.021	5,100T
U'-2	113 1/2- 117 1/2	Keel, top of inner bottom	Centerline	**	0.010	2,500T

(See NOTES on following page)

TOP SECRET

## NOTES

- # The prefix U denotes peak strain gages; U' denotes time-recording strain gages.
- / The maximum apparent stress was obtained by multiplying the unit strain by an assumed modulus of  $30 \times 10^6$  pounds per square inch.
- \* As pointed out in the text the errors in these values may be large.
- \*\* The elongation in 120 inches at this location was less than 0.01 inch.

The magnitudes of the measured strains and their corresponding stresses indicate that the structural response of the BRISCOE, BRACKEN, and NIAGARA to the blast of Test Able was well below the elastic limit. The data fail to define any pattern of overall bending of the ships. The general impression gained from the results is that the ships were merely shaken up by the air blast and that the results reflect only local stresses caused by shock.

It is very probable that rotation of the ends of the strain gages mounted on the lightly stiffened decks appreciably magnified the effects of local buckling so that the results obtained from these gages are of little value as far as true strain is concerned. The gages mounted on the keel and on the heavy port and starboard stringers are relatively free from such distortion by virtue of their location on stiff deep members and the data derived from them are, therefore, more truly indicative of the actual strains induced in the ships. The strains measured by these gages are quite small and fairly consistent.

Figure 3 is an enlarged reproduction of the time-strain record yielded by the gage mounted on the keel of the BRACKEN, in the gasoline stowage space. This record is of interest because it reflects the occurrence of two distinct shocks, one waterborne, the other airborne. The time interval between the two shocks, both of which produced strains of very small magnitude, was approximately 2.4 seconds. Similar records were obtained from the other time-strain gage on the BRACKEN and from the two gages on the BRISCOE. The two shocks reached the BRISCOE approximately 1.7 seconds apart. There is no evidence of wave action on any of these four records. No time-strain records were obtained on the NIAGARA which was actually a spare or standby ship, and the gages installed on this vessel were not supplied with power.

## TEST RESULTS AND DISCUSSION - TEST BAKER

### DISPLACEMENTS MEASURED ON SUBMARINES

The submarines SKIPJACK, SEARAVEN, TUNA, APOGON, and DENTUDA were submerged for Test Baker; the SKATE and the PARCHE were on the surface. Displacements were measured at the same locations as in Test Able and are listed in Tables 1 to 6. No records were recovered from the APOGON which was sunk in this test.

TABLE 1

Displacements Measured on SS-184, SKIPJACK						
Gage	Frame	Gage Location		Direction	Displacement in Inches	
		Inches above Platform			In	Out
		Port	Starboard			
N-1	23	39	39	Athwart.	3.60*	--
N-2	27	--	--	Vertical	0.45	0.31
N-3	175	47	12	Athwart.	1.19**	--
N-4	168	--	--	Vertical	0.43	0.29

\* A permanent set of 2.9 inches was indicated at this location.

\*\* A permanent set of 0.9 inch was indicated at this location.

TABLE 2

Displacements Measured on SS-196, SEARAVEN						
Gage	Frame	Gage Location		Direction	Displacement in Inches	
		Inches above Platform			In	Out
		Port	Starboard			
N-1	24	42	42	Athwart.	0.075	0.065
N-2	27 1/2	--	--	Vertical	0.090	0.045
N-3	176	21	61	Athwart.	0.040	0.030
N-4*	173	--	--	Vertical	0.040	0.030

\* This gage was placed to port of the vertical centerline; 21 inches at the top and 14 inches at the bottom.

TABLE 3

<u>Displacements Measured on SS-203, TUNA</u>						
<u>Gage</u>	<u>Frame</u>	<u>Gage Location</u>		<u>Direction</u>	<u>Displacement in Inches</u>	
		<u>Inches above Platform</u>	<u>Inches above Platform</u>		<u>In</u>	<u>Out</u>
		<u>Port</u>	<u>Starboard</u>			
N-1	21	48	18	Athwart.	0.130	0.050
N-2	30	--	--	Vertical	0.135	0.015
N-3	118	52	44	Athwart.	0.070	0.055
N-4	112	--	--	Vertical	0.090	--

TABLE 4

<u>Displacements Measured on SS-305, SKATE</u>						
<u>Gage</u>	<u>Frame</u>	<u>Gage Location</u>		<u>Direction</u>	<u>Displacement in Inches</u>	
		<u>Inches above Platform</u>	<u>Inches above Platform</u>		<u>In</u>	<u>Out</u>
		<u>Port</u>	<u>Starboard</u>			
N-1	22	23	23	Athwart.	0.080	0.025
N-2	29	--	--	Vertical	0.110	0.065
N-3	120	40	57	Athwart.	0.105	0.075
N-4	113	--	--	Vertical	0.120	0.065

TABLE 5

Displacements Measured on SS-335, DENTUDA						
		Gage Location				
		Inches above Platform		Displacement in Inches		
Gage	Frame	Port	Starboard	Direction	In	Out
N-1	21	34	34	Athwart.	0.145	0.030
N-2	30	--	--	Vertical	0.085	0.055
N-3	120	50	56	Athwart.	0.105	0.010
N-4	113	--	--	Vertical	0.125	0.105

TABLE 6

Displacements Measured on SS-384, PARCHE						
Gage	Frame	Gage Location		Direction	Displacement in Inches	
		Inches above Platform			In	Out
		Port	Starboard			
N-1	22	42	42	Athwart.	0.020	0.020
N-2	30	--	--	Vertical	0.015	0.020
N-3	120	42	42	Athwart.	0.020	0.020
N-4	113	--	--	Vertical	0.015	0.005

The records from the SKIPJACK, the submarine nearest the center of explosion, were recovered several weeks after Test Baker when the vessel was brought to the surface. The large athwartships displacements measured in both torpedo rooms attest to the severity of the load imposed on the SKIPJACK which lay port-side-on to the bomb. The magnitudes of the two vertical displacements are almost equal, but, in the forward room, the athwartships displacement is about three times as large as in the after torpedo room.

The inward displacements measured on the SEARAVEN, DENTUDA, and TUNA were of the same order of magnitude as would result

from submergence to a depth of about 200 feet.

The maximum displacement recorded on the SKATE, which was on the surface only a short distance farther from the center of the explosion than the submerged SKIPJACK, was no greater than would be produced by diving to a depth of 200 feet. The PARCHE, also on the surface for Test Baker, was hardly affected by the explosion; the measured displacements were insignificant.

#### DISPLACEMENTS MEASURED ON ATTACK TRANSPORTS

Displacements measured on the transports BRISCOE, BRACKEN, and NIAGARA at the same locations as in Test Able are listed in Tables 7, 8 and 9.

TABLE 7

<u>Displacements Measured on APA-65, BRISCOE - TEST BAKER</u>						
<u>Gage</u>	<u>Placement of Gage</u>	<u>Frame</u>	<u>Gage Location</u>		<u>Displacement in Inches</u>	
			<u>Vertical</u>	<u>Athwart.</u>	<u>Inward</u>	<u>Outward</u>
N-1	Athwart.	49 1/2	2nd Pltfm level	Port stringer to stbd stringer	0.23	0.57
N-2	Vertical	50	1st Pltfm to top of inner bottom	13 ft. 5 in. to port of centerline	0.80	0.45
N-3	Athwart.	115	1st Pltfm level	Port stringer to stbd stringer	0.52	0.23
N-4	Vertical	116	Main Dk. to 2nd Pltfm	14 ft. to port of centerline	0.71	0.35

TABLE 8

<u>Displacements Measured on APA-65, BRACKEN-TEST BAKER</u>						
<u>Gage</u>	<u>Placement</u>	<u>Gage Location</u>		<u>Displacement in Inches</u>		
	<u>of Gage</u>	<u>Frame</u>	<u>Vertical</u>	<u>Athwart.</u>	<u>Inward</u>	<u>Outward</u>
N-1	Athwart.	49 1/2	2ndPltfm level	Port stringer to stbd stringer	0.04	0.13
N-2	Vertical	50	1stPltfm to top of inner bottom	15 ft. to port of centerline	0.18	0.16
N-3	Athwart.	115	1stPltfm level	Port stringer to stbd stringer	0.29	0.07
N-4	Vertical	116	Main Dk. to 2nd Pltfm	14 ft. 2 in. to port of centerline	0.21	0.10

TABLE 9

<u>Displacements Measured on APA-87, NIAGARA - TEST BAKER</u>						
<u>Gage</u>	<u>Placement</u>	<u>Gage Location</u>		<u>Displacement in Inches</u>		
	<u>of Gage</u>	<u>Frame</u>	<u>Vertical</u>	<u>Athwart.</u>	<u>Inward</u>	<u>Outward</u>
N-1	Athwart.	49 1/2	2ndPltfm level	Port stringer to stbd stringer	No record	
N-2	Vertical	50	1stPltfm to top of inner bottom	13 ft. 7 in. to port of centerline	0.05	0.03
N-3	Athwart.	116	1stPltfm level	Port stringer to stbd stringer	0.09	0.03
N-4	Vertical	117	Main Dk. to 2nd Pltfm.	13 ft. 6 in. to port of centerline	0.05	0.01

The displacements recorded on the BRISCOE, the nearest of these ships to the explosion of Test Baker, while considerably greater than those produced on this vessel by Test Able, again were smaller than was expected and indicate a response below the elastic limit of the structure. The maximum displacement, which was vertical and inward, occurred in the forward hold. The two athwartships movements were comparable to each other in magnitude but were opposite in direction; outward in the forward hold and inward in the after hold. The outward movement recorded by Gage N-1 in the forward hold is believed due to a tendency of the ship's sides to spread apart as a result of the bowing of the bottom due to the upward force acting on it. The athwartships gage in the after hold did not record this effect presumably because the second platform served to restrain the sides of the ship from moving outward. This restraining effect was absent in the forward hold where the gage spanned the ship at the level of the second platform with no deck between the gage and the bottom of the ship. This difference in the construction of the two holds can be seen from Figure 2 and Photographs 186 to 190.

On the BRACKEN the maximum displacement was athwartships and inward in the after hold. As in the case of the BRISCOE, discussed above, this displacement was opposite in direction to that recorded by the athwartships gage in the forward hold.

The relatively large vertical displacements recorded on the BRISCOE and on the BRACKEN reflect the predominantly vertical motion of the ships which would be expected from an underwater explosion.

The displacements measured on the NIAGARA which was on the outskirts of the target array were very small.

#### STRAINS MEASURED ON ATTACK TRANSPORTS

In Tables 10, 11 and 12 are listed the apparent stresses derived from strains measured on the BRISCOE, BRACKEN, and NIAGARA at the same locations as in Test Able.

TABLE 10

Apparent Stresses Derived from Strains Measured on APA-65,  
BRISCOE - TEST BAKER

# Gage	Gage Location			Total Elongation in Inches per 120 Inches		Maximum Apparent Stress psi $\pm$
	Frame	Vertical	Athwart.	Compression	Tension	
U-1	42-46	Wthr.Dk.	48'' from Pt. Shell	0.114	0.168	41,000T*
U-2	42-46	Wthr.Dk.	48'' from Sb. Shell	0.148	0.084	36,200C*
U-3	42-46	Main Dk.	48'' from Pt. Shell	0.029	0.068	16,600T*
U-4	42-46	Main Dk.	48'' from Sb. Shell	0.029	0.040	9,800T*
U-5	42-46	2ndPltfm level	Port stringer	0.027	0.033	8,100T
U-6	42-46	2ndPltfm level	Stbd stringer	0.025	0.032	7,800T
U'-1	42-46	Keel, top of inner bottom	Centerline	0.031	0.053	13,300T
U-7	110-114	Wthr.Dk.	48'' from Pt. Shell	0.064	0.031	15,600C*
U-8	110-114	Wthr.Dk.	48'' from Sb. Shell	0.061	0.028	14,900C*
U-9	110-114	Main Dk.	48'' from Pt. Shell	0.056	0.029	13,700C*
U-10	110-114	Main Dk.	48'' from Sb. Shell	0.021	0.028	6,800T*
U-11	110-114	1stPltfm level	Port stringer	0.041	0.100	24,400T
U-12	110-114	1stPltfm level	Stbd stringer	0.028	0.028	6,800TC
U'-2	113 1/2- 117 1/2	Keel, top of inner bottom	Centerline	0.039	0.059	14,800T

(See NOTES following Table 12)

TOP SECRET

TABLE 11

Apparent Stresses Derived from Strains Measured on APA-64,  
BRACKEN - TEST BAKER

# Gage	Gage Location			Total Elongation in Inches per 120 Inches		Maximum Apparent Stress psi $\pm$
	Frame	Vertical	Athwart.	Compression	Tension	
U-1	42-46	Wthr.Dk.	48'' from Pt. Shell	0.046	0.018	11,200C*
U-2	42-46	Wthr.Dk.	48'' from Sb. Shell	0.069	0.025	16,800C*
U-3	42-46	Main Dk.	48'' from Pt. Shell	**	0.038	9,300T*
U-4	42-46	Main Dk.	48'' from Sb. Shell	0.033	0.018	8,100C*
U-5	42-46	2ndPltfm level	Port stringer	**	0.022	5,400T
U-6	42-46	2ndPltfm level	Stbd stringer	0.015	0.018	4,400T
U'-1	42-46	Keel, top of inner bottom	Centerline	0.010	0.011	2,700T
U-7	110-114	Wthr.Dk.	48'' from Pt. Shell	0.026	**	6,300C*
U-8	110-114	Wthr.Dk.	48'' from Sb. Shell	0.030	0.013	7,300C
U-9	110-114	Main Dk.	48'' from Pt. Shell	0.016	**	3,900C*
U-10	110-114	Main Dk.	48'' from Sb. Shell	0.012	0.010	2,900C*
U-11	110-114	1stPltfm level	Port stringer	**	0.014	3,400T
U-12	110-114	1stPltfm level	Stbd stringer	**	0.023	5,600T
U'-2	113 1/2- 117 1/2	Keel, top of inner bottom	Centerline	**	0.013	3,300T

(See NOTES following Table 12)

TABLE 12

Apparent Stresses Derived from Strains Measured on APA-87,  
 NIAGARA - TEST BAKER

# Gage	Gage Location			Total Elongation in Inches per 120 Inches		Maximum Apparent Stress
	Frame	Vertical	Athwart.	Compression	Tension	psi $\pm$
U-1	42-46	Wthr.Dk.	48'' from Pt. Shell	0.020	0.017	4,900C*
U-2	42-46	Wthr.Dk.	48'' from Sb. Shell	0.034	0.016	8,300C*
U-3	42-46	Main Dk.	48'' from Pt. Shell	**	0.010	2,400T*
U-4	42-46	Main Dk.	48'' from Sb. Shell	0.017	0.029	7,100T*
U-5	42-46	2ndPltfm level	Port stringer	**	0.020	4,900T
U-6	42-46	2ndPltfm level	Stbd stringer	**	**	
U'-1	42-46	Keel, top of inner bottom	Centerline	**	**	
U-7	110-114	Wthr.Dk.	48'' from Pt. Shell	0.017	0.025	6,100T*
U-8	110-114	Wthr.Dk.	48'' from Sb. Shell	**	**	
U-9	110-114	Main Dk.	48'' from Pt. Shell	**	**	
U-10	110-114	Main Dk.	48'' from Sb. Shell	**	**	
U-11	110-114	1stPltfm level	Port stringer	**	0.020	4,900T
U-12	110-114	1stPltfm level	Stbd stringer	**	**	
U'-2	113 1/2- 117 1/2	Keel, top of inner bottom	Centerline	**	**	

(See NOTES on following page)

## NOTES

- # The prefix U denotes peak strain gages; U' denotes time-recording strain gages.
- † The maximum apparent stress was obtained by multiplying the unit strain by an assumed modulus of elasticity of  $30 \times 10^6$  psi.
- \* As pointed out in the text the errors in these values may be large.
- \*\* The elongation in 120 inches at this location was less than 0.01 inch.

As was the case in Test Able, the largest strains were measured in the forward locations on the weather deck of the three transports. As pointed out previously, these records include the effects of local buckling of the unstiffened decks. The strains at the more reliable gage locations on the keel were of much lesser magnitude. With regard to tension and compression, the consistency of the data is poor and no clear picture of systematic behavior of the ships can be deduced from the maximum apparent stresses. Predominantly tensile strains were recorded by ten of the fourteen gages on the BRISCOE; by seven of fourteen gages on the BRACKEN; and by five of the seven gages on the NIAGARA for which records are tabulated. There is little correlation between the nature of the strains, i.e., tensile or compressive, and the vertical or athwartships locations where they were measured. On the BRISCOE, for example, the four predominantly compressive strains were measured by gages located on the port and starboard sides of the weather deck; aft; on the port side of the main deck, aft; and on the starboard side of the weather deck, forward.

By virtue of their locations on the keel, the time-strain gages are considered to have yielded the most reliable records. The strains measured by these gages on the BRACKEN and on the BRISCOE are predominantly tensile and are of comparable magnitude at both locations on each ship.

Enlarged reproductions of portions of time-strain records obtained from keel gages on the BRISCOE and BRACKEN are given in Figure 4. The records are too compressed and indistinct to define the sequence of strain at the instant the shock reached the ships. It appears, however, that at least one cycle of tensile and compressive strain preceded the maximum recorded strain. The relatively slow disc speed of  $1 \frac{1}{2}$  revolutions per minute, which caused the compressed records, was selected with the expectation that the explosion and its aftermath might cause appreciable strains over a period of perhaps two minutes. Actually, the duration of the entire visible records was only about 19 seconds which amounts to less than one-half a revolution of the disc.

Figure 4a shows the initial portion of the record obtained from the keel gage in the forward hold of the BRISCOE. The peak strain is followed by a train of reversals having a frequency of about 15 cycles per second superimposed on a frequency of two cycles per second which is apparently the two-noded vertical vibration of the ship.

The record yielded by the keel gage in the gasoline stowage space of the BRISCOE, Figure 4b, exhibits a peak strain comparable in magnitude to that recorded in the forward hold. Failure of the gage scribe to scratch continuously accounts for the gaps in the portion of the record shown in the figure; the remainder of the record showing clear repetitions of the two-noded vertical vibration of two cycles per second is continuous.

The keel gage in the forward hold of the BRACKEN yielded the record given in Figure 4c. The occurrence of two shocks, one waterborne the other airborne, at a time interval of about 25 seconds is indicated on this record. Other instrumentation groups, who noted the same effect on both the BRACKEN and the BRISCOE, estimate the interval between shocks to be 2.3 seconds for the former ship and 1.35 seconds for the latter. The estimate of 1.35 seconds would place the second shock on the BRISCOE at point A of Figure 4a where there is some indication of additional disturbance of the record of Figure 4b falls at the beginning of the first gap where the gage scribe failed to record.

VARIATION OF STRAINS AND DISPLACEMENTS WITH DISTANCE  
TEST ABLE

SUBMARINES

The deflections measured on all submarines except the SKATE are too small to permit a vessel-to-vessel analysis of the relation between distance from the bomb and the measured deflections or displacements of the hulls. In most cases, the displacements are below, or barely exceed, the limits of accuracy of the gages.

The comparison of deflections measured at Bikini with those recorded during previous deep dives confirms the finding of the inspection boards that all the submarines were outside the effective range of the bomb on Test Able as far as damage to the hulls was concerned. Although the SKATE, the submarine nearest the blast, sustained severe damage topside, there was no damage to her pressure hull.

ATTACK TRANSPORTS

The displacements measured on the BRISCOE, BRACKEN, and NIAGARA and the horizontal distances from these ships to the bomb are given in Table 13.

TABLE 13

Horizontal Distance from Bomb versus Measured Displacements,  
Attack Transports BRISCOE, BRACKEN, and NIAGARA

Ship	Horizontal Distance from Bomb in Yards	Inward Displacement in Inches			
		N-1	N-2	N-3	N-4
BRISCOE	1710	0.14	0.15	0.45	0.24
BRACKEN	2160	0.07	0.14	0.27	0.19
NIAGARA	3410	0.02	0.05	0.12	0.07

The ratios of the athwartships displacements recorded on the BRISCOE to the corresponding displacements measured on the BRACKEN are 2.0 and 1.7 for the forward and after holds respectively. The average of these ratios is about 1.8 which is in good agreement with the ratio of 1.7 between the peak blast pressures measured on these two ships by another Bureau of Ships instrumentation group. No blast pressure measurements were made on the NIAGARA.

The vertical displacements on the BRISCOE and the BRACKEN cannot be compared validly with the blast pressures because, unlike the athwartships gages, the vertical gages could not be installed between portions of the ships directly exposed to the blast; they were shielded to an unknown extent by intervening structure.

Reliable data are too scanty to establish a definite relationship between measured strain and distance from the bomb for the instrumented transports. The three ships were all outside the lethal range of the bomb and suffered only superficial damage.

VARIATION OF STRAINS AND DISPLACEMENTS WITH DISTANCE  
TEST BAKER

SUBMARINES

As indicated in Table 14 the two instrumented submarines nearest the bomb were sunk in Test Baker whereas the other five suffered little or no damage.

TABLE 14

Equivalent Submergences for Instrumented Submarines at Various Distances from Center of Explosion

<u>Submarine</u>	<u>Test Condition</u>	<u>Horizontal Distance from Bomb Yards</u>	<u>Damage</u>	<u>Approximate Equivalent Submergence in Feet*</u>
SKIPJACE	Submerged	810	Sunk	-
APOGON	Submerged	870	Sunk	-
SKATE	Surfaced	930	Negligible	200
SEARAVEN	Submerged	1450	Negligible	220
DENTUDA	Submerged	1510	Negligible	190
PARCHE	Surfaced	1610	None	50
TUNA	Submerged	1840	Negligible	200

- \* The equivalent submergence is the depth at which the submarine hull would sustain the same deflections as produced by the atomic bomb explosion. The estimates are based on a comparison of the deflections measured at Bikini with those measured on sister submarines during deep-submergence trials.

It is roughly estimated that the lethal range of the atomic bomb with respect to submerged submarines is about 1100 yards. No closer

definition of the radius within which severe damage would be inflicted is possible because there was a gap of about 600 yards between the APOGON which was sunk and the SEARAVEN which was practically undamaged.

Displacements observed on deep dives were compared with those measured at comparable gage locations at Bikini. Estimates of equivalent submergences, based on these comparisons and listed in the table, appear to be consistent with distance except in the case of the TUNA. The submergence value given for this vessel is comparable in magnitude to those listed for the SEARAVEN and the DENTUDA although these two submarines were about 390 yards and 330 yards closer to the bomb respectively.

### ATTACK TRANSPORTS

The three instrumented transports were outside the effective range of the bomb of Test Baker as far as structural damage is concerned.

There is no consistent relation between the displacements measured on the BRISCOE and those measured at corresponding locations on the BRACKEN apparently because of the wide difference in the orientation of the two ships with respect to the bomb; the BRISCOE lay nearly portside-on while the BRACKEN took the blast almost stern-on. The displacements on the BRISCOE, anchored about 910 yards from the center of explosion, were about 3 1/2 times greater on the average than those measured on the BRACKEN which was about 1490 yards from the bomb. At the forward and after strain gage locations on the keel of the BRISCOE the maximum stresses were about 13,300 and 14,800 pounds per square inch respectively; at both keel gage locations on the BRACKEN the maximum stresses were only about 3,300 pounds per square inch or less than one-fourth as much as was indicated on the BRISCOE.

As was the case in Test Able, the NIAGARA was far out in the target array and suffered no strains or displacements large enough to be of any significance.

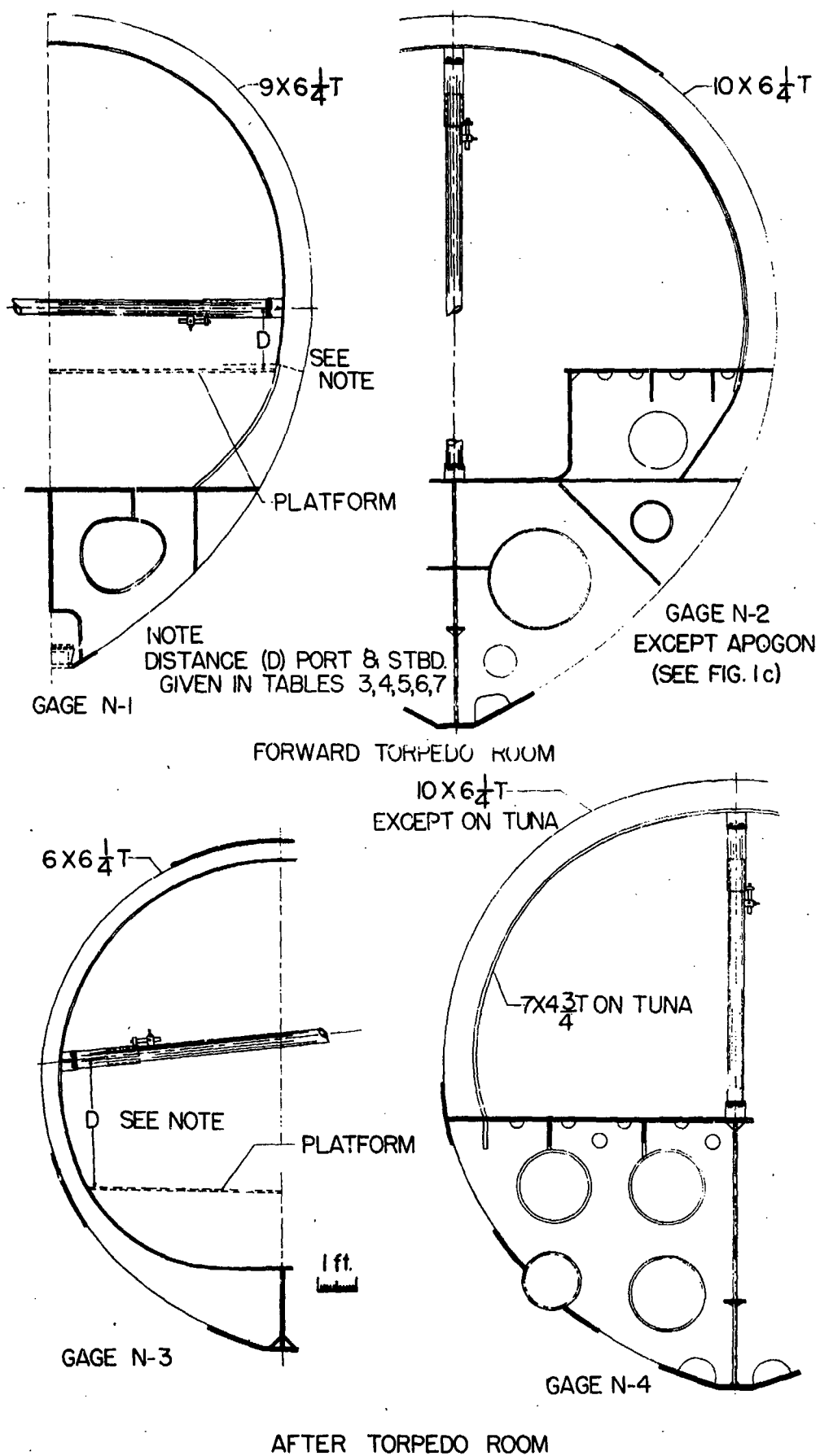


FIGURE 1a

TYPICAL FRAME STRUCTURES AT DISPLACEMENT GAGE LOCATIONS ON  
SUBMARINES APOGON, DENTUDA, SKATE, PARCHE AND TUNA

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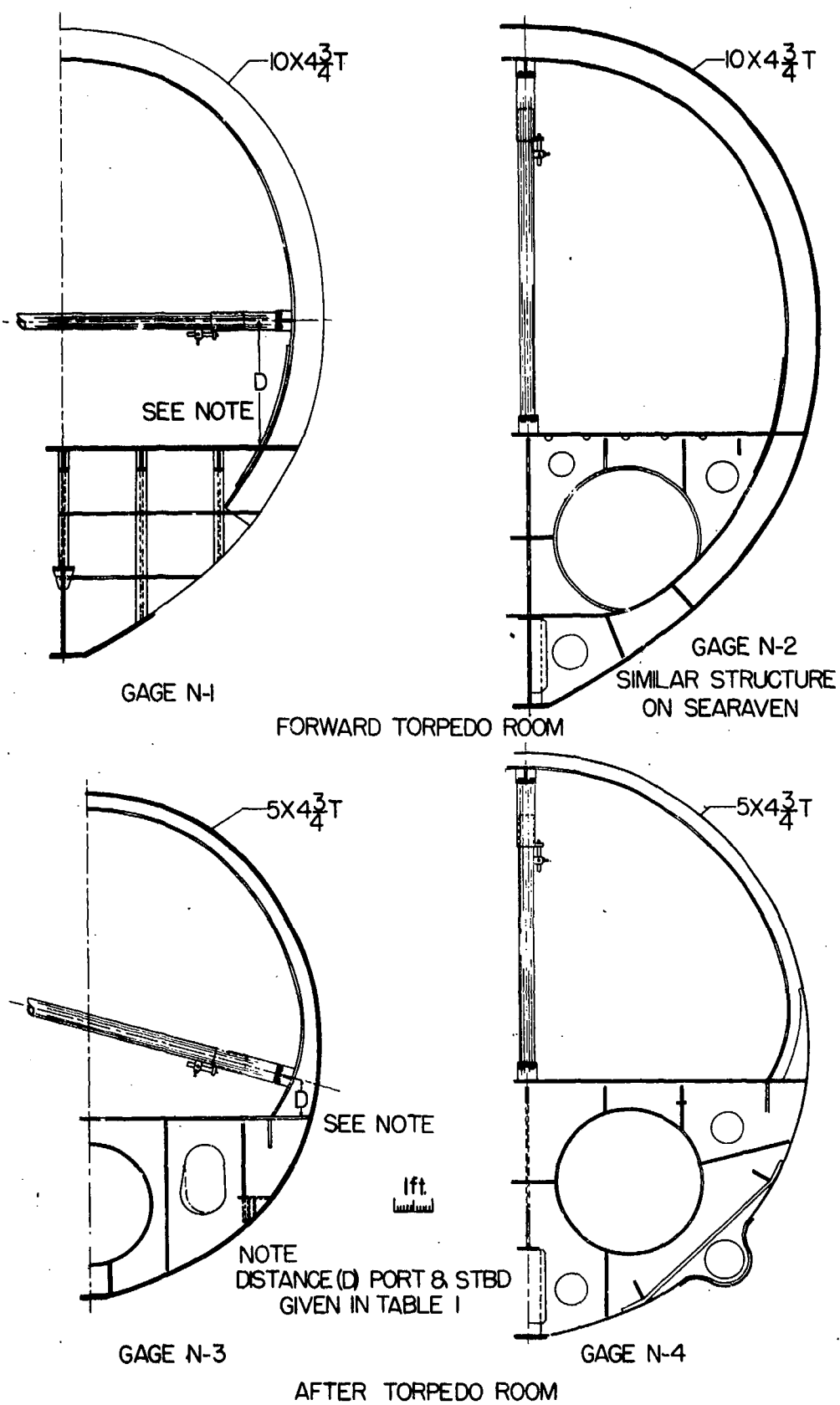
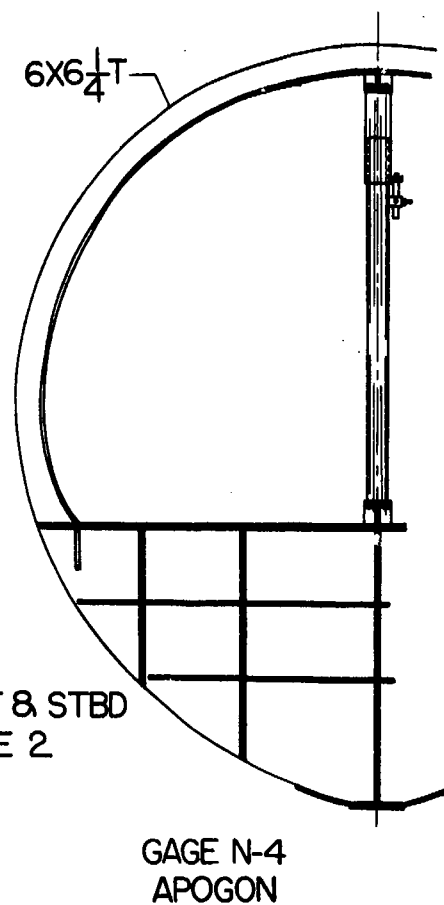
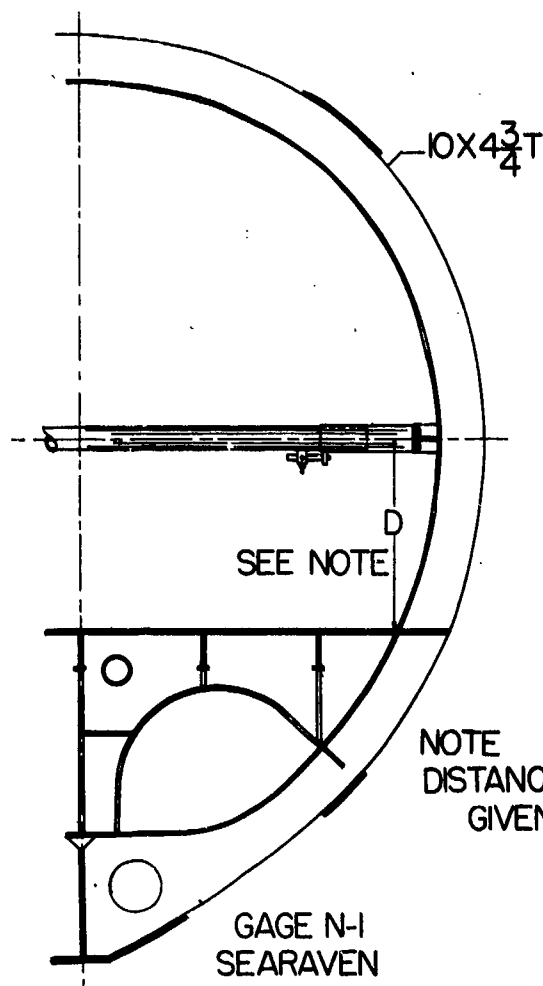


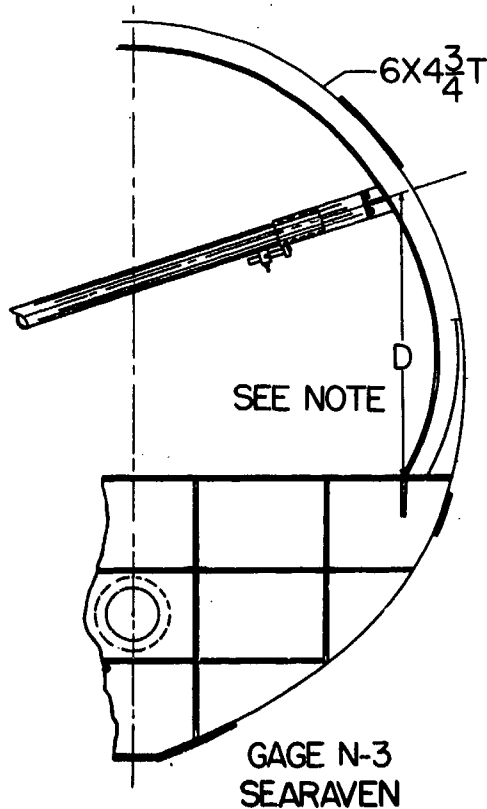
FIGURE 1b  
FRAME STRUCTURES AT DISPLACEMENT GAGE  
LOCATIONS ON SUBMARINE SKIPJACK

**TOP SECRET**



NOTE  
DISTANCE (D) PORT & STBD  
GIVEN IN TABLE 2

1ft.  
[Scale bar]



PLAN OF FRAME 173, SEARAVEN,  
GAGE N-4 UNAVAILABLE

SEE FIGURE 1b FOR STRUCTURE AT  
LOCATION OF GAGE N-2

FIGURE 1c  
FRAME STRUCTURES AT DISPLACEMENT  
GAGE LOCATIONS ON SUBMARINES  
SEARAVEN AND APOGON

**TOP SECRET**

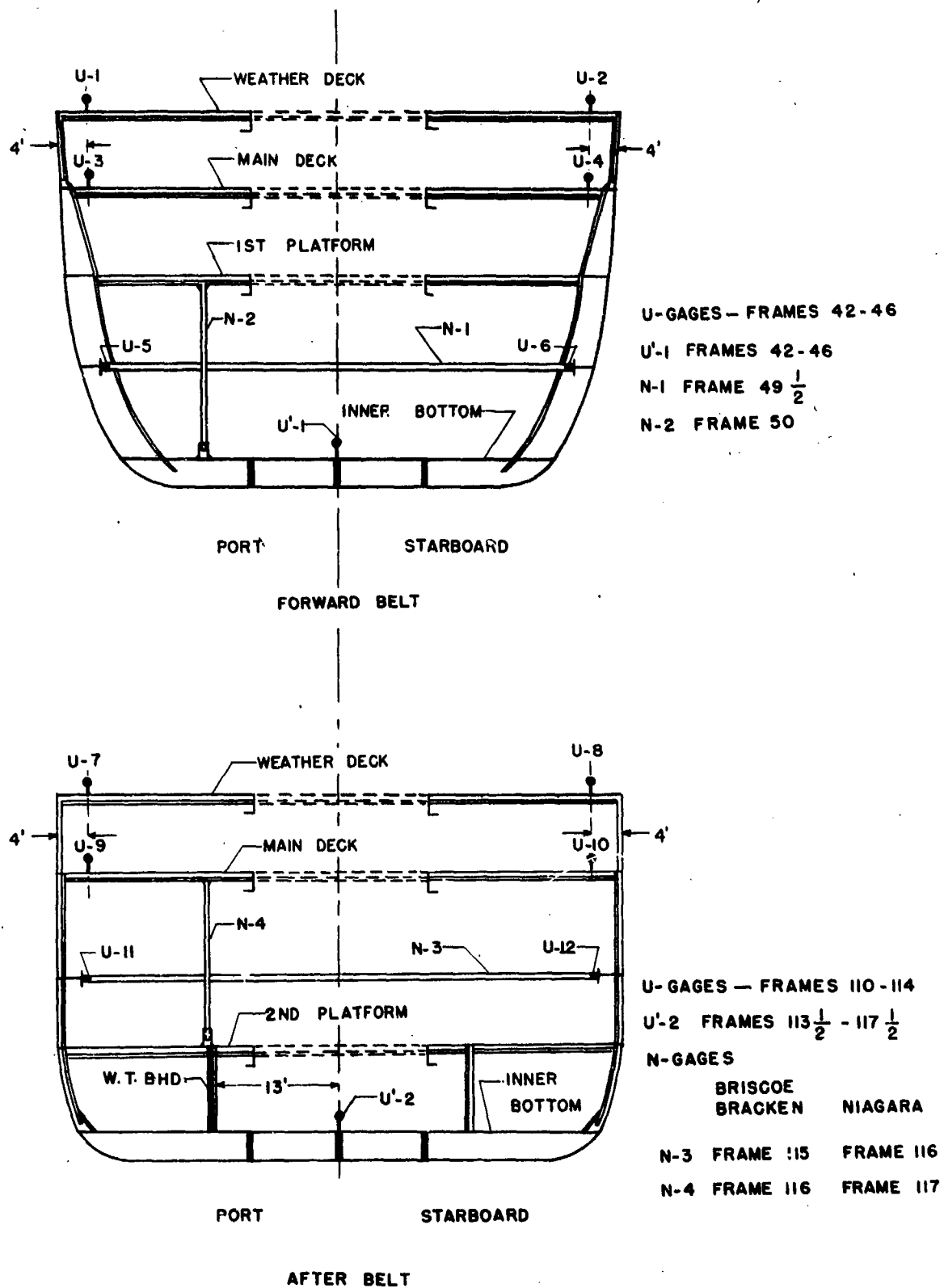


FIGURE 2 — GENERAL ARRANGEMENT OF STRAIN GAGES AND DISPLACEMENT GAGES  
ON ATTACK TRANSPORTS

**TOP SECRET**

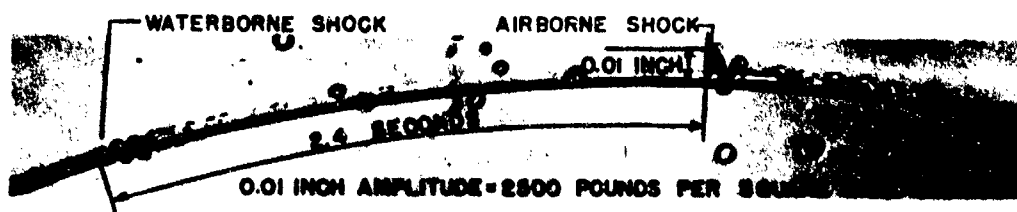
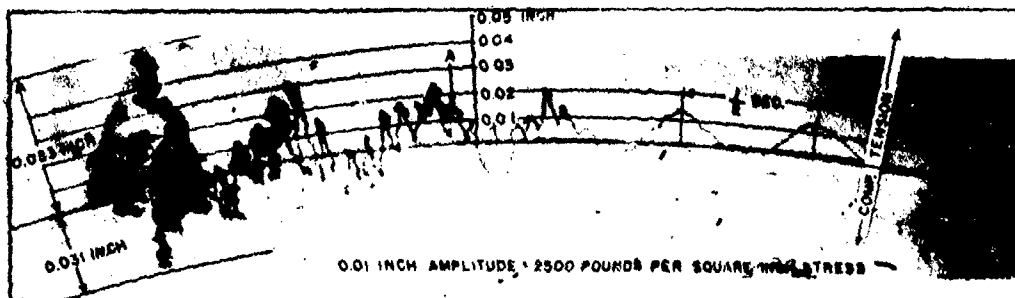


FIGURE 3- TIME-STRAIN RECORD OBTAINED FROM KEEL GAGE  
 LOCATED IN GASOLINE STOWAGE SPACE BELOW  
 AFTER HOLD OF APA 64, USS BRACKEN

**TOP SECRET**

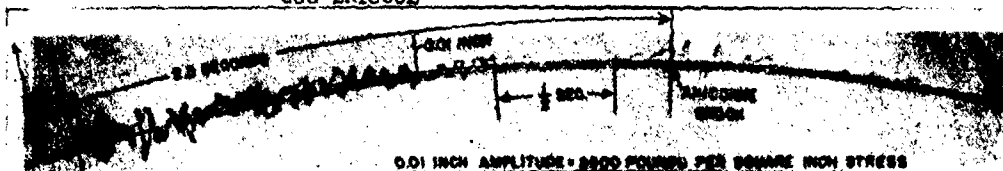
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(a) Time-Strain Record Obtained from Keel Gage in Forward Hold of APA65, USS BRISCOE



(b) Time-Strain Record Obtained from Keel Gage in Gasoline Stowage Space Below After Hold of APA65, USS BRISCOE



(c) Time-Strain Record Obtained from Keel Gage in Forward Hold of APA64, USS BRACKEN

Figure 4 - Portions of Time-Strain Records Obtained from Keel Gages on APA's 65 and 64, USS BRISCOE and USS BRACKEN.

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6801 Telegraph Road  
Alexandria, Virginia 22310-3398

TRC

18 April 1997

MEMORANDUM FOR DEFENSE TECHNICAL INFORMATION CENTER  
ATTENTION: OMI/Mr. William Bush (Security)

SUBJECT: Distribution Statement Changes

The Defense Special Weapons Agency has reviewed and approved for **public release, all of the listed report; distribution statement "A"** now applies:

~~AD-473893L~~

XRD-173-Appendix 16 *Cancelled*

AD-473913

XRD-194-Section 3

AD-B210866

WT-1321-Supp ✓ *Completed 2-7-2000*

AD-473915

XRD-196-Section 5.

*Arldith Jarrett*

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